International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN(P): 2249-6890; ISSN(E): 2249-8001
Vol. 7, Issue 2, Apr 2017, 127-134

THE COMPARISON OF DEVIATIONS OF FREEFORM SURFACES USING RE-ENGINEERING BY NON-CONTACT SCANNERS

SREERAM REDDY GUNDETI & SREE KRISHNA GUTHENA

Department of Mechanical Engineering, Vidya Jyothi Institute of Technology, Hyderabad, Telangana, India

ABSTRACT

There are various types of optical and Laser 3D scanners used for capturing the point cloud data in reverse engineering approach. The present article deals with the comparison of EINSCAN Scanner and the V5 PERCEPTRON 3D LASER SCANNER for reverse engineering a freeform surface. A freeform surface is modelled and machined using Computer numerical control machine. The multiple scanning operations are done on this physical part by both the scanners individually. The obtained data was converted to ASCII (.asc) file format type and the data is evaluated using Reverse engineering software. In this comparison the standard and deviation distribution are evaluated by comparing the RE-model with original CAD model independently. In conclusion, V5 perceptron has small variation ranges than Einscan when observing the deviation status at pre-defined points(L1 to L18) and percentage of points (Einscan– 13.7% of pts. in range of 0.2300 to 0.3200, V5 Perceptron – 37.2% of pts. In range of -0.0216 to 0.0216) in deviation distribution of each scanners.

KEYWORDS: Non-Contact Scanners, Freeform Surface & Comparison of Scanners

Received: Jan 30, 2017; **Accepted:** Mar 12, 2017; **Published:** Mar 16, 2017; **Paper Id.:** IJMPERDAPR201712

Original Article

INTRODUCTION

The duplication of existing part by capturing the component's features and physical dimensions is Reverse engineering. The non-contact scanner acquires geometry data from the existing physical part. This data which is obtained from scanner is used to construct a three-dimensional model of scanned part. This reverse engineering techniques involves measuring of an object and reconstructing it as 3D model [1][3]. The measuring of 3D physical models can be done in various ways such as 3D scanning, industrial CT scanning. That can be used to accomplish reverse engineering, inspection, rapid prototyping and cultural heritage documentation. The measured data which is acquired through this are represented as point cloud data but these data lacks in the topographical information, so these point cloud data are processed and modelled which eventually gives data in useable format. One of the most crucial process in reverse engineering is data digitization there are many process or standards for acquiring measurements of the physical part model. The dimensional accuracy and the head to head comparison with Coordinate measuring machine is made by scanning [2].

3D scanners are classified into two types, they are:

- **Contact Type Scanner [4]:** These scanners require mechanical contact with between the scanner and component. Example: Coordinate measuring machine (CMM). These are conventional process of scanning which was used predominantly before the existence of non-contact type of scanner, contact type of scanner generally touches the physical part model during the scanning freeform surface over the

physical part due to this contact phenomenon this scanners usually causes some destruction on the physical part model.

- **Non-Contact Type Scanner:** which do not have any Mechanical contact with the component. They scan the component using laser, optical etc. In this type scanning device will not be in touch with the physical part model and this type of scanners are most accurate and widespread. Inherently non-contact scanner are not destructive to the part, these generally provides faster data collection rates comparatively.

  These scanners are further classified based on scanning method:

- **Laser Scanning Method:** Principle behind this scanning is triangulation.
- **Optical Scanning Method:** This scanner work on the photographic principle.
- **Mechanical Scanning Method:** These are a contact type scanners, were these are divided into CMM's and Measuring arms.
- **Ultrasonic Scanning Method:** Scanning by ultrasonic waves, by using laser the angle of impact and reflection period are sensed by ultrasonic waves.

SCANNERS

Einscan Scanner

It is white light phenomenon/ is a combination of structured light 3D scanner and turntable/tripod (Figure 1 and 2). And the specifications of the scanner are given in the below Table 1.

Table 1

Scan Volume	**200*200*200 mm(Automatic Scan) and 700*700*700mm (Free Scan)**
Resolution	1.3 Mega Pixel
Point to point distance	0.17~.02mm
Accuracy	≤0.1mm
Scan Speed	< 3mins (Automatic scan) and <10sec (Free scan)

This scanner having a light which is focused on the part which is placed on a turntable and with help of EINSCAN which is placed on a tripod is used to scan [5]. This scanned data point is available in STL, IGES etc., they use geomagic software to convert them.

Figure 1: Scanning Performed on Freeform Surface

Figure 2: Einscan with Structured Light

V5 Perceptron 3D Laser Scanner

which uses twin camera technology can see two sides of an object at once (Figure 3), which produces high quality data and high dynamic rage for scanning and has high resolution of points along the laser line[6]. And the specifications of the scanner are given in the below Table 2.

Table 2

Scan Rate	458,000 Points/Second
Point to point Distance	12 microns
Laser Bandwidth	140mm
Accuracy	24 microns 2 sigma

This V5 sensor has the ability to scan data on dark and reflective surfaces and projects an accurate trapezoidal representation of the field, this enables the user to become familiar with good scanning practices and minimizing overlapping data. This is suitable for various industries and applications, from the factory floor to inspection rooms and laboratories.

Figure 3: Performing Scanning Operation on Freeform Surface using V5 Perceptron 3D Scanner

METHEDOLOGY

In this the comparative study between the scanners is made using reverse engineering technique. Here the scanning is done by the scanners having white light phenomenon and twin camera technology. In white light phenomenon, the point data is obtained by focusing white light on the part for acquisition and in twin camera technology, the data is

captured over the two side of the object at once. After that the digitized data is converted to ASCII (.asc) file format. Further the obtained deviations (between RE-model and original CAD model) with each scanner are compared with each other [7], to find which scanner gives the best accuracy. The below flow chart gives the followed procedure/method.

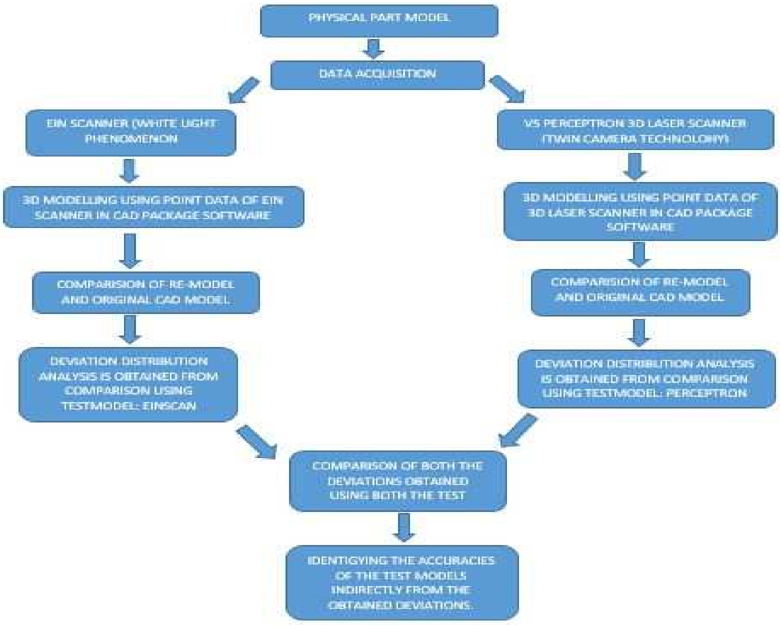


Figure 4

EXPERIMENTAL WORK

In this reverse engineering the data is collected/captured using two non-contact scanner which are having white light phenomenon and twin camera technology. A component is selected for the testing and satisfying scanning criteria which is having a complex freeform shape (shown in Figure 5) for scanning which is hard to be scanned using 3D scanners.

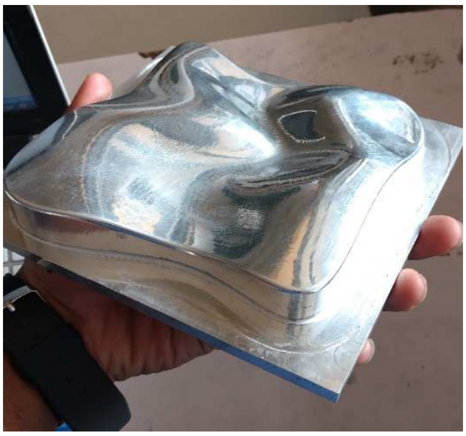


Figure 5: CNC Machined Part (Freeform Surface Model)

This no. of data points obtained by EinScanis 661922 and by V5 Perceptron is 134653. After multiple scans the obtained data is converted to ASCII (.asc) file format type shown in Figure 6,. This point cloud data is imported into Reverse Engineering Software were it is used reconstruct the freeform surface and this RE-model is then compared to the original cad model to evaluate deviations. Few steps to be followed before initializing the comparison between RE-model

and CAD model, and those are Noise reduction, Sampling, Wrapping Defect, Diagnostics, Smoothing a Mesh surface, Simplifying Model, Filling holes in model [8] (shown in Figure 7).

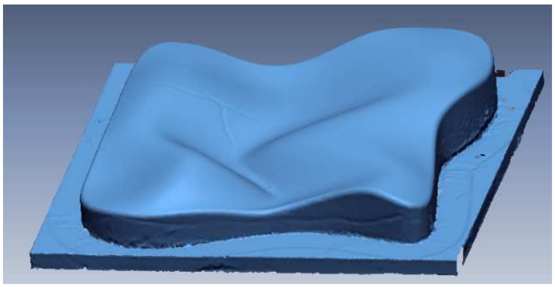


Figure 6: Point Data in (asc) File Format

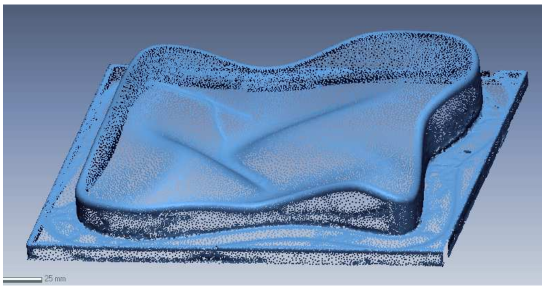


Figure 7: After the Fillerting Operations

After these operations the model is established in X, Y and Z planes on both the test and reference objects and the test object is reoriented so that three planes match the reference objects. The 3D compare operation of Models is generated and a colour coded mapping of the differences between the selected objects are seen. The deviations which are reported as the shortest distance from the test to any point on the reference. It gives the standard deviation and average deviation values individually for different test models and the outputs/deviations are compared between the Einscan and V5 perceptron 3D scanner and evaluate better scan performance on the freeform surface.

RESULTS AND DISCUSSIONS

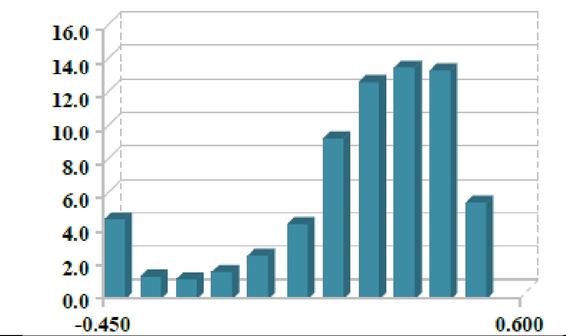
Deviations in shape and orientation and dimensions are taken into consideration as evaluating characteristics. The deviations which obtained independently from RE-model and CAD model are compared with the tolerance value of 0.5mm. In comparison of

Table 3: Deviation Distribution

Einscan Scanner				V5 Perceptron 3D Scanner			
>=Min	<Max	# Points	%	>=Min	<Max	# Points	%
-0.5000	-0.4100	31437	4.7494	-0.4313	-0.3630	0	0.0000
-0.4100	-0.3200	8806	1.3304	-0.3630	-0.2947	22	0.0163
-0.3200	-0.3200	7721	1.1665	-0.2947	-0.2264	18	0.0134
-0.2300	-0.2300	10677	1.6130	-0.2264	-0.1581	86	0.0639
-0.1400	-0.1400	17128	2.5876	-0.1581	-0.0899	2234	1.6591
-0.0500	0.0500	29562	4.4661	-0.0899	-0.0216	31580	23.4529
0.0500	0.1400	63388	9.5764	-0.0216	0.0216	50200	37.2810
0.1400	0.2300	85560	12.9260	0.0216	0.0899	42896	31.8567
0.2300	0.3200	91335	13.7985	0.0899	0.1581	6149	4.5666
0.3200	0.4100	90208	13.6282	0.1581	0.2264	825	0.6127
0.4100	0.5000	38096	5.7554	0.2264	0.2947	415	0.3082

Table 3: Contd.,

				0.2947	0.3630	187	0.1389
				0.3630	0.4313	40	0.0297
Out of Upper Critical		30256	4.45709	Out of Upper Critical		1	0.0007
Out of Lower Critical		157748	23.83138	Out of Lower Critical		0	0.0000



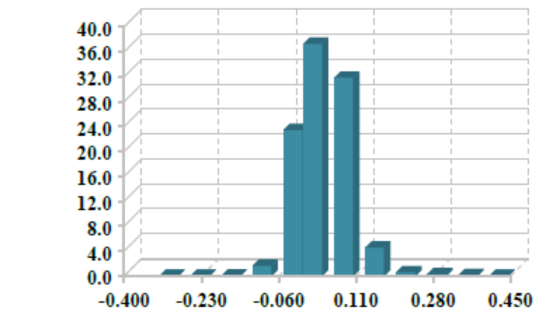
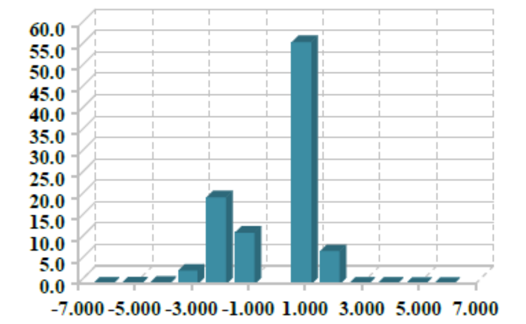


Table 4: Standard Deviations

Einscan Scanner			V5 Perceptron 3D Scanner		
Distribution (+/-)	**# Points**	**%**	**Distribution (+/-)**	**# Points**	**%**
-6 * Std. Dev.	262	0.0396	-6 * Std. Dev.	34	0.0253
-5 * Std. Dev.	639	0.0965	-5 * Std. Dev.	14	0.0104
-4 * Std. Dev	1678	0.2535	-4 * Std. Dev	121	0.0899
-3 * Std. Dev.	20653	3.1202	-3 * Std. Dev.	1630	1.2105
-2 * Std. Dev.	134014	20.2462	-2 * Std. Dev.	14239	10.5746
-1 * Std. Dev.	79527	12.0146	-1 * Std. Dev.	58378	43.3544
1 * Std. Dev.	373941	56.4932	1 * Std. Dev.	39310	29.1936
2 * Std. Dev.	50954	7.6979	2 * Std. Dev.	17771	13.1950
3 * Std. Dev.	155	0.0234	3 * Std. Dev.	2013	1.4950
4 * Std. Dev.	86	0.0130	4 * Std. Dev.	500	0.3713
5 * Std. Dev.	9	0.0014	5 * Std. Dev.	350	0.2599
6 * Std. Dev.	4	0.0006	6 * Std. Dev.	293	0.2176



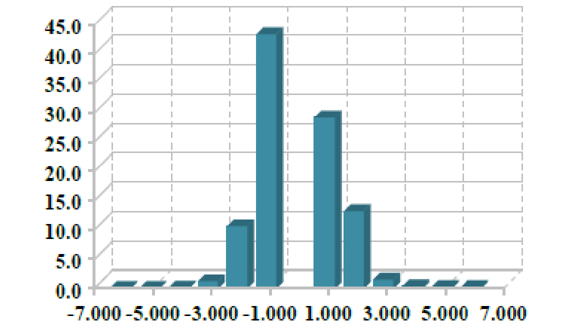


Table 5: Location Set

						Einscan		Perceptron	
Name	**Upper Tol**	**Lower Tol**	**Ref. X**	**Ref. Y**	**Ref. Z**	**Dev.**	**Status**	**Dev.**	**Status**
L1	0.1372	-0.1372	-137.18	11.94	109.74	-06604	FAIL	-0.0676	PASS
L2	0.1372	-0.1372	-109.74	16.85	137.18	0.1434	FAIL	0.0142	PASS
L3	0.1372	-0.1372	-109.74	19.68	82.30	-0.0343	PASS	0.0234	PASS
L4	0.1372	-0.1372	-109.74	19.55	27.43	0.4053	FAIL	-0.0428	PASS
L5	0.1372	-0.1372	-109.74	23.99	54.87	0.2614	FAIL	-0.0130	PASS
L6	0.1372	-0.1372	-109.74	21.33	109.74	0.2347	FAIL	-0.0004	PASS
L7	0.1372	-0.1372	-82.30	12.83	54.87	0.2087	FAIL	0.0593	PASS
L8	0.1372	-0.1372	-82.30	11.02	82.30	0.3293	FAIL	0.0580	PASS
L9	0.1372	-0.1372	-82.30	11.94	27.43	0.4377	FAIL	0.0810	PASS

Table 5: Contd.,

L10	0.1372	-0.1372	-82.30	16.57	109.74	0.4261	FAIL	-0.0559	PASS
L11	0.1372	-0.1372	-54.87	18.28	27.43	0.3821	FAIL	0.0559	PASS
L12	0.1372	-0.1372	-54.87	12.59	109.74	0.3598	FAIL	0.0480	PASS
L13	0.1372	-0.1372	-54.87	21.65	82.30	0.4122	FAIL	-0.0105	PASS
L14	0.1372	-0.1372	-54.87	15.82	54.87	0.2826	FAIL	0.0664	PASS
L15	0.1372	-0.1372	-27.43	24.49	54.87	0.2332	FAIL	0.0094	PASS
L16	0.1372	-0.1372	-27.43	20.86	82.30	0.1151	PASS	0.011	PASS
L17	0.1372	-0.1372	-27.43	24.67	27.43	0.2375	FAIL	-0.0085	PASS
L18	0.1372	-0.1372	-27.43	21.22	109.74	0.1316	PASS	-0.0272	PASS

In this, the Deviation status is compared at 18 predefined points by PASS or FAIL. This Table 3., shows that the perceptron 3D scanner has passed at all the points i.e. it has the small variation in the deviation, while the Einscan has maximum fails at L1, L2, L4, L5, L6, L7, L8, L9, L10, L11, L12, L13, L14, L15 and L17, in this it says that there is large variations in the deviations obtained from the comparison of RE-model and Original CAD model. In the below Figures 6 & 7. The colour coded mapping of the deviation is shown[9].

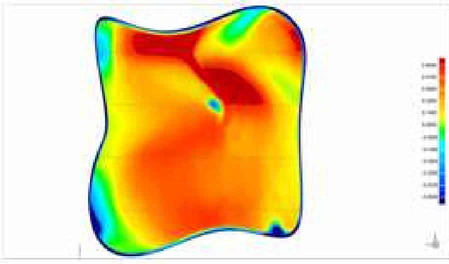


Figure 8: Deviation Analysis: Einscan

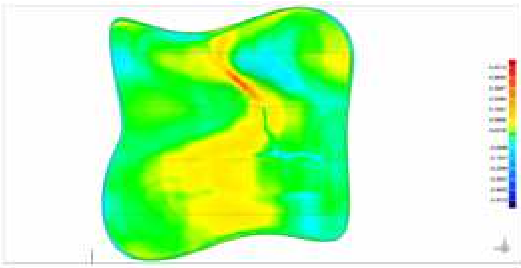


Figure 9: Deviation Analysis: Perceptron

Table 6: Deviation Analysis

Einscan Scanner		V5 Perceptron 3D Scanner	
Reference Model	**Freeform22 Cat Change**	**Reference Model**	**Freeform22 Cat Change**
Test Model	Einscan	Test Model	Perceptron
No. of Data Points	661922	No. of Data Points	134653
Tolerance Type	3D Deviation	Tolerance Type	3D Deviation
Units	Mm	Units	Mm
Max. Critical	0.5000	Max. Critical	0.4313
Max. Nominal	0.0500	Max. Nominal	0.0216
Min. Nominal	-0.0500	Min. Nominal	-0.0216
Min. Critical	-0.5000	Min. Critical	-0.4313
Deviation			
Max. Upper Deviation	4.7559	Max. Upper Deviation	0.4313
Max. Lower Deviation	-3.0262	Max. Lower Deviation	-0.3590
Average Deviation	0.2775/-0.5651	Average Deviation	0.0480/-0.0318

Table 6: Contd.,			
Standard Deviation	0.4657	Standard Deviation	0.538

CONCLUSIONS

For evaluation, Complex freeform surface (having deep curved profiles) is used. The comparative results of study tell that scanner with V5 Perceptron (twin camera technology) scanner have greater accuracy than EINSCAN.

- In this comparison the V5 PERCEPTRON has small range variation, by having the maximum percentage of points in the range of -0.060 to 0.110 in Deviation Distribution, 58378 points in -1* standard dev. Distribution – 39310 points in 1* standard dev. Distribution are far better when compared to EINSCAN.
- The Deviation status at 18 predefined points (L1 to L18) in upper and lower tolerance range depicted as shown in Table.3.
- This shows that V5 perceptron 3D scanner is better and fast at scanning the complex freeform surface than Einscan.

The results which are obtained from the individual scans were summarized in the Table 3, 4, 5, 6 and the comparison of RE-model and CAD model is shown. The variation ranges are small in V5 Perceptron and consistent when compared to the Einscan, as Perceptron has minimum point to point distance and has high resolution to the Complex freeform surface. By increasing the no. of scans more accurate and exact evaluation of dev. Distribution are obtained[10]. Further by using Capture 3D scanner the deviations obtained are compared with this V5 perceptron and EINSCAN to obtain better evaluation.

REFERENCES

1. *G. Sreeram Reddy†*, Manzoor Hussain‡, J. Jagadesh Kumar† and V. V. Satyanarayana†, Experimental Investigation on Reverse Engineering of a Typical Freeform Surface using Portable Laser Arm Scanner, 05 Sept 2016, Vol.6, No.5 (Oct 2016).*
2. *Christopher j. rolls-, CAD model construction based on CMM and Laser scanner data for reverse engineering,2001*
3. *Mr. S. P. Sathya Prasanth1 DR. V. Dhanalakshmi2, Comparison of Data Capturing Techniques and Analysis of Part Model in Reverse Engineering.*
4. *Tomaz Brajlih1,* – Tadej Tasic1 – Igor Drstvensek1 – Bogdan Valentan1 – Miodrag Hadzistevic2 – Vojko Pogacar1 – Joze Balic1 – Bojan Acko1, Possibilities of Using Three-Dimensional Optical Scanning in Complex Geometrical Inspection, Strojniškivestnik - Journal of Mechanical Engineering 57(2011)11, 826-833.*
5. *http://www/einscan.com/tech-specs*
6. *http://www.europac3d.com/3d-laser-scanning/v5-perceptron-scanner/*
7. *Spencer Onuh, Nick Bennett, and Jim Baker, Rapid Prototyping: Practical Approach to Enabling Reverse Engineering, Proceedings of SPIE, 2001*
8. *Varady, T. Martin, Reverse engineering of geometric models-an introduction, computer aided design, v.29, 1997, pp 255-268*
9. *Ngozi Sherry Ali, Reverse Engineering of Automotive Parts Applying Laser Scanning and Structured Light Techniques, MAY 2005.*
10. *TeodorTóth*, JozefŽivčák, A Comparison of the Outputs of 3D Scanners, Procedia Engineering 69 (2014) 393 – 401.*